United States
Environmental Protection
Agency

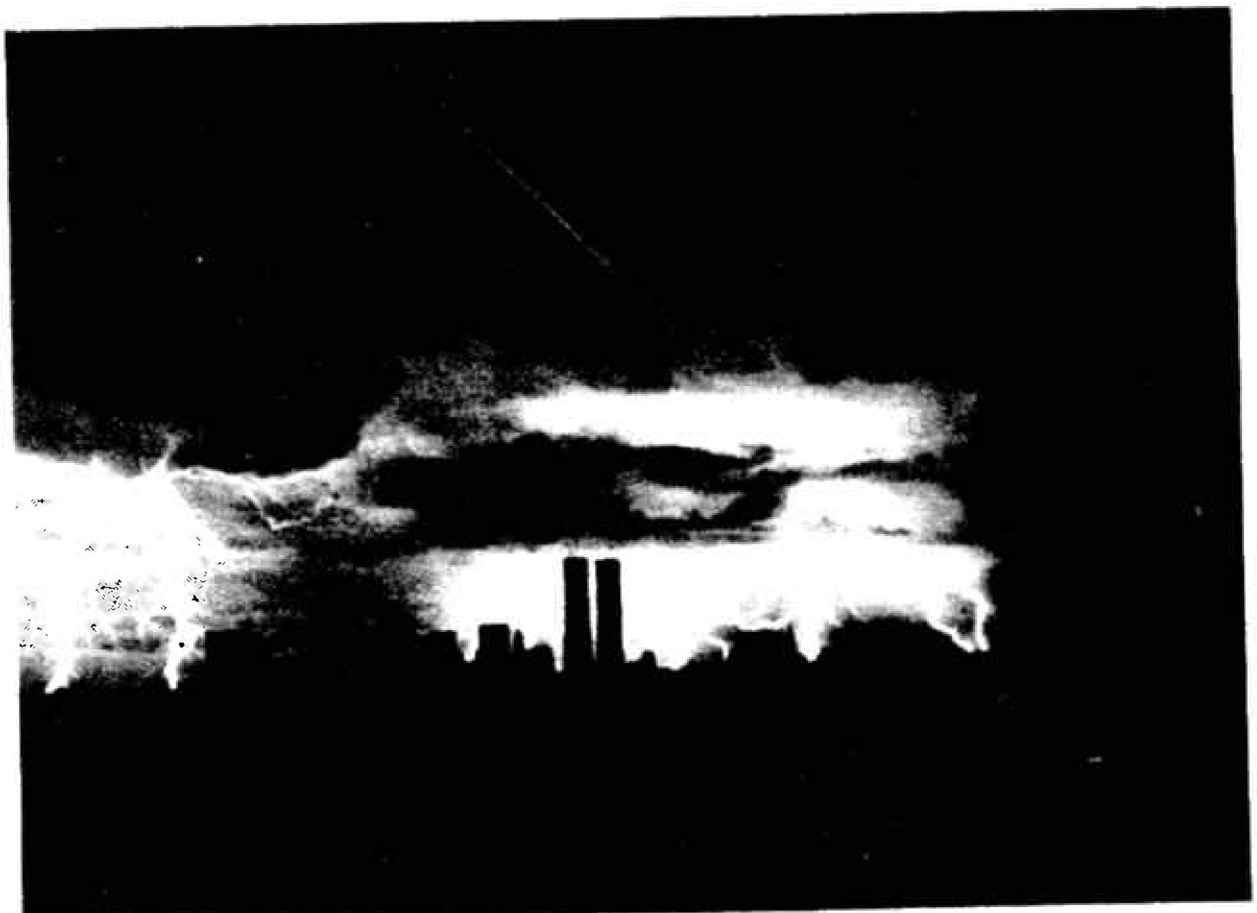
Water Planning Division
WH-554
Washington, DC 20460

December 1983

Water

Results of the Nationwide Urban Runoff Program

Executive Summary



RESULTS

OF THE

NATIONWIDE URBAN RUNOFF PROGRAM

December, 1983

EXECUTIVE SUMMARY

Water Planning Division

U.S. Environmental Protection Agency

Washington, D.C. 20460

National Technical Information Service (NTIS)
Accession Number: PB84-185545

DISCLAIMER

ACKNOWLEDGEMENTS

The Nationwide Urban Runoff Program was unusual in its large scale, covering a broad spectrum of technical and planning issues at many geographic locations. Because the program placed such emphasis on tailoring the results to support the planning process, it involved many participants - some from EPA, some from other federal agencies, and many from state, regional, and local planning agencies and other consultants.

The program was developed, implemented, and managed by the Water Planning Division, Office of Water, at EPA Headquarters, Washington, D.C. Principal contributors were: Dennis N. Athayde, Program Manager; and Patrice M. Bubar, Norman A. Whalen, Stuart S. Tuller, and Phillip H. Graham, all of whom served as Project Officers. Additional contributions from EPA personnel came from Rod E. Frederick and Richard P. Healy (Monitoring and Data Support Division), Richard Field (Storm and Combined Sewer Section, EPA Office of Research and Development), and many project staff in the various EPA Regional Offices.

As described elsewhere, much of the field work, water quality analysis, and data analysis was performed by the U.S. Geological Survey (USGS), under a Memorandum of Agreement with EPA. Both District Offices and National Headquarters participated actively. The contributions of Messrs. Ernest Cobb and David Lystrom are especially acknowledged.

Members of the project team which provided essential strategic, technical, and management assistance to the EPA Water Planning Division through a contract with Woodward-Clyde Consultants were: Gail B. Boyd, David Gaboury, Peter Mangarella, and James D. Sartor (Woodward-Clyde Consultants); Eugene D. Driscoll (E. D. Driscoll and Associates); Philip E. Shelley (EG&G Washington Analytical Services Center, Inc.); John L. Mancini (Mancini and DiToro Consultants); Robert E. Pitt (private consultant); Alan Plummer (Alan Plummer and Associates); and James P. Heaney and Wayne C. Huber (University of Florida).

The principal writers of this report were Dennis N. Athayde (EPA), Philip E. Shelley (EG&G Washington Analytical Services Center, Inc.), Eugene D. Driscoll (E. D. Driscoll & Associates), and David Gaboury and Gail B. Boyd (Woodward-Clyde Consultants).

EXECUTIVE SUMMARY

BACKGROUND

The water quality effects of stormwater pollution received little attention prior to 1960. Stormwater concerns were primarily related to drainage problems. As stormwater pollution began to be investigated, the work, reported by EPA and published in professional journals, tended to focus on determining (a) the type and amount of pollutants involved and/or (b) methods to reduce the loads. However, such reports and articles gave limited consideration to either the level of improvement attainable or the need to improve quality of the receiving water body associated with the study. A conclusion common to all such reports was that not enough was known about stormwater, and recommendations for further study and more data were the norm. A tangible result of the uncertain attitude in this area is the fact that stormwater controls for water quality have been implemented in so few places throughout the nation. Thus, there has been a critical need to objectively examine the situation. This need led to the development of the Nationwide Urban Runoff Program (NURP).

The overall goal of NURP was to develop information that would help provide local decision makers, States, EPA, and other interested parties with a rational basis for determining whether or not urban runoff is causing water quality problems and, in the event that it is, for postulating realistic control options and developing water quality management plans, consistent with local needs, that would lead to implementation of least cost solutions. It is also hoped that this information base will be used to help make the best possible policy decision on Federal, State, and local involvement in urban stormwater runoff and its control. Among the many objectives of NURP was the assembly of an appropriate data base and the development of analytical methodologies that would allow us to examine such issues as:

- The quality characteristics of urban runoff, and similarities or differences at different urban locations;

- The extent to which urban runoff is a significant contributor to water quality problems across the nation; and

- The performance characteristics and the overall effectiveness and utility of management practices for the control of pollutant loads from urban runoff.

Water quantity problems are relatively easy to identify and describe. Water quality problems, on the other hand, tend to be more elusive because their definition often involves some subjective considerations, including experiential aspects and expectations of the populace. They are not immediately obvious and are usually less dramatic than, for example, floods. They also tend to vary markedly with locality and geographic regions within the country. Thus, a methodological approach to the determination of water quality problems is essential if one is to consider the relative role of urban runoff as a contributor. An important finding of the work conducted during NURP was to learn to avoid the following simplistic logic train: (a) water quality problems are caused by pollutants, (b) there are pollutants in urban runoff, therefore, (c) urban runoff causes "problems". The unspoken implication is that a "problem" by definition requires action, and any type of "problem" warrants equally vigorous action. It becomes clear that a more fundamental and more precise definition of a water quality "problem" from urban runoff is necessary. For this purpose, NURP adopted the following three-level definition:

- Impairment or denial of beneficial uses;

- Water quality criterion violation; and

- Local public perception.

The foregoing levels of problem definition provide an essential framework within which to discuss water quality problems associated with urban runoff. However, it is important to understand that when one is dealing at a local level all three elements are typically present. Thus, it is up to the local decision makers, influenced by other levels of support and concern, to carefully weigh each, prior to making a final decision about the existence and extent of a problem and how it is to be defined.

The NURP studies have greatly increased our knowledge of the characteristics of urban runoff, its effects upon designated uses, and of the performance efficiencies of selected control measures. They have also confirmed earlier impressions that some States and local communities have actually begun to develop and implement stormwater management programs incorporating water quality objectives. However, such management initiatives are, at present, scattered and localized. The experience gained from such efforts is both needed and sought after by many other States and localities. Documentation, evaluation, refinement and transfer of management and financing mechanisms/ arrangements, of simple and reliable problem assessment methodologies, and of implementation guidance which can be used by planners and officials at the State and local level are urgently needed as is a forum for the sharing of experiences by those already involved, both among themselves and with those who are about to address nonpoint source issues.

CONCLUSIONS

The following summarizes NURP's conclusion relating to its major objectives and is based on the results presented in Chapters 6, 7, and 8 of the report. Conclusions reached by the individual NURP projects are also presented to further support the results of the national level analysis.

URBAN RUNOFF CHARACTERISTICS

General

Field monitoring was conducted to characterize urban runoff flows and pollutant concentrations. This was done for a variety of pollutants at a substantial number of sites distributed throughout the country. The resultant data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provide a basis for identifying patterns of similarities or differences and testing their significance.

Urban runoff flows and concentrations of contaminants are quite variable. Experience shows that substantial variations occur within a particular event and from one event to the next at a particular site. Due to the high variability of urban runoff, a large number of sites and storm events were monitored, and a statistical approach was used to analyze the data. Procedures are available for characterizing variable data without requiring knowledge of or existence of any underlying probability distribution (nonparametric statistical procedures). However, where a specific type of probability distribution is known to exist, the information content and efficiency of statistical analysis is enhanced. Standard statistical procedures allowed probability distributions or frequency of occurrence to be examined and tested. Since the underlying distributions were determined to be adequately represented by the lognormal distribution, the log (base e) transforms of all urban runoff data were used in developing the statistical characterizations.

The event mean concentration (EMC), defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary water quality statistic. Event mean concentrations were based on flow weighted composite samples for each event at each site in the accessible data base. EMCs were chosen as the primary water quality characteristic subjected to detailed analysis, even though it is recognized that mass loading characteristics of urban runoff (e.g., pounds/acre for a specified time interval) is ultimately the relevant factor in many situations. The reason is that, unlike EMCs, mass loadings are very strongly influenced by the amount of precipitation and runoff, and estimates of typical annual mass loads will be biased by the size of monitored storm events. The most reliable basis for characterizing annual or seasonal mass loads is on the basis of EMC and site-specific rainfall/runoff characteristics.

Establishing the fundamental distribution as lognormal and the availability of a sufficiently large population of EMCs to provide reliability to the statistics derived has yielded a number of benefits, including the ability to provide:

- Concise summaries of highly variable data

- Meaningful comparisons of results from different sites, events, etc.

- Statements concerning frequency of occurrence. One can express how often values will be expected to exceed various magnitudes of interest.

- A more useful method of reporting data than the use of ranges; one which is less subject to misinterpretation

- A framework for examining "transferability" of data in a quantitative manner

Conclusions

1. Heavy metals (especially copper, lead and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff. End-of-pipe concentrations exceed EPA ambient water quality criteria and drinking water standards in many instances. Some of the metals are present often enough and in high enough concentrations to be potential threats to beneficial uses.

   All 13 metals on EPA's priority pollutant list were detected in urban runoff samples, and all but three at frequencies of detection greater than 10 percent. Most often detected among the metals were copper, lead, and zinc, all of which were found in at least 91 percent of the samples.

   Metal concentrations in end-of-pipe urban runoff samples (i.e., before dilution by receiving water) exceeded EPA's water quality criteria and drinking water standards numerous times. For example, freshwater acute criteria were exceeded by copper concentrations in 47 percent of the samples and by lead in 23 percent. Freshwater chronic exceedances were common for lead (94 percent), copper (82 percent), zinc (77 percent), and cadmium (48 percent). Regarding human toxicity, the most significant pollutants were lead and nickel, and for human carcinogenesis, arsenic and beryllium. Lead concentrations violated drinking water criteria in 73 percent of the samples.

   It should be stressed that the exceedances noted above do not necessarily imply that an actual violation of standards will exist in the receiving water body in question. Rather, the enumeration of exceedances serves a screening function to identify those heavy metals whose presence in urban runoff warrants high priority for further evaluation.

   Based upon the much more extensive NURP data set for total copper, lead, and zinc, the site median EMC values for the median urban site are: Cu = 34 μg/l, Pb = 144 μg/l, and Zn = 160 μg/l. For the 90th percentile urban site the values are: Cu = 93 μg/l, Pb = 350 μg/l, and Zn = 500 μg/l. These values are suggested to be appropriate for planning level screening analyses where data are not available.

   Some individual NURP project sites (e.g., at DC1, MD1, NH1) found unusually high concentrations of certain heavy metals (especially copper and zinc) in urban runoff. This was attributed by the projects to the effect of acid rain on materials used for gutters, culverts, etc.

2. The organic priority pollutants were detected less frequently and at lower concentrations than the heavy metals.

Sixty-three of a possible 106 organics were detected in urban runoff samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22 percent), followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported at frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single halogenated aliphatic.

Criteria exceedances were less frequently observed among the organics than the heavy metals. One unusually high pentachlorophenol concentration of 115 μg/l resulted in exceedances of the freshwater acute and organoleptic criteria. This observation and one for chlordane also exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentachlorophenol, bis (2-ethylhexyl) phthalate, gamma-BHC, chlordane, and alpha-endosulfan. All other organic exceedances were in the human carcinogen category and were most serious for alpha-hexachlorocyclohexane (alpha-BHC), gamma-hexachlorocyclohexane (gamma-BHC or Lindane), chlordane, phenanthrene, pyrene, and chrysene.

The fact that the NURP priority pollutant monitoring effort was limited to two samples at each site leaves us unable to make many generalizations about those organic pollutants which occurred only rarely. We can speculate that their occurrences tend to be very site specific as opposed to being a generally widespread phenomena, but much more data would be required to conclusively prove this point.

3. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in many surface waters, even those providing high degrees of dilution.

Fecal coliform counts in urban runoff are typically in the tens to hundreds of thousand per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100 ml. During cold weather, fecal coliform counts are more typically in the 1,000/100 ml range, which is the median for all sites. Thus, violations of fecal coliform standards were reported by a number of NURP projects. High fecal coliform counts may not cause actual use impairments, in some instances, due to the location of the urban runoff discharges relative to swimming areas or shellfish beds and the degree of dilution/dispersal and rate of die off. The same is true of total coliform counts, which were found to exceed EPA water quality criteria in undiluted urban runoff at virtually every site every time it rained.

The substantial seasonal differences noted above do not correspond with comparable variations in urban activities. The NURP analyses as well as current literature suggest that fecal coliform may not be the most appropriate indicator organism for identifying potential health risks when the source is stormwater runoff.

4. Nutrients are generally present in urban runoff, but with a few individual site exceptions, concentrations do not appear to be high in comparison with other possible discharges to receiving water bodies.

   NURP data for total phosphorus, soluble phosphorus, total kjeldahl nitrogen, and nitrate plus nitrite as nitrogen were carefully examined. Median site EMC median concentrations in urban runoff were TP = 0.33 mg/l, SP = 0.12 mg/l, TKN = 1.5 mg/l, and NO2+3 - N = 0.68 mg/l. On an annual load basis, comparison with typical monitoring data, literature values, and design objectives for discharges from a well run secondary treatment plant suggests that mean annual nutrient loads from urban runoff are around an order of magnitude less than those from a POTW.

5. Oxygen demanding substances are present in urban runoff at concentrations approximating those in secondary treatment plant discharges. If dissolved oxygen problems are present in receiving waters of interest, consideration of urban runoff controls as well as advanced waste treatment appears to be warranted.

   Urban runoff median site EMC median concentrations of 9 mg/l BOD5 and 65 mg/l COD are reflected in the NURP data, with 90th percentile site EMC median values being 15 mg/l BOD5 and 140 mg/l COD. These concentrations suggest that, on an annual load basis, urban runoff is comparable in magnitude to secondary treatment plant discharges.

   It can be argued that urban runoff is typically well oxygenated and provides increased stream flow and, hence, in view of relatively long travel times to the critical point, that dissolved oxygen problems attributable solely to urban runoff should not be widespread occurrences. No NURP project specifically identified a low DO condition resulting from urban runoff. Nonetheless, there will be some situations where consideration of urban runoff controls for oxygen demanding substances in an overall water quality management strategy would seem appropriate.

6. Total suspended solids concentrations in urban runoff are fairly high in comparison with treatment plant discharges. Urban runoff control is strongly indicated where water quality problems associated with TSS, including build-up of contaminated sediments, exist.

   There are no formal water quality criteria for TSS relating to either human health or aquatic life. The nature of the suspended solids in urban runoff is different from those in treatment plant discharges, being higher in mineral and man-made products (e.g., tire and street surface wear particles) and somewhat lower in organic particulates. Also, the solids in urban runoff are more likely to have other contaminants adsorbed onto them. Thus, they cannot be simply considered as benign, nor do they only pose an aesthetic issue. NURP did not examine the problem of contaminated sediment build-up due to urban runoff, but it undeniably exists, at least at some locations.

   The suspended solids in urban runoff can also exert deleterious physical effects by sedimenting over egg deposition sites, smothering juveniles, and altering benthic communities.

On an annual load basis, suspended solids contributions from urban runoff are around an order of magnitude or more greater than those from secondary treatment plants. Control of urban runoff, as opposed to advanced waste treatment, should be considered where TSS-associated water quality problems exist.

7. A summary characterization of urban runoff has been developed and is believed to be appropriate for use in estimating urban runoff pollutant discharges from sites where monitoring data are scant or lacking, at least for planning level purposes.

   As a result of extensive examination, it was concluded that geographic location, land use category (residential, commercial, industrial park, or mixed), or other factors (e.g., slope, population density, precipitation characteristics) appear to be of little utility in consistently explaining overall site-to-site variability in urban runoff EMCs or predicting the characteristics of urban runoff discharges from unmonitored sites. Uncertainty in site urban runoff characteristics caused by high event-to-event variability at most sites eclipsed any site-to-site variability that might have been present. The finding that EMC values are essentially not correlated with storm runoff volumes facilitates the transfer of urban runoff characteristics to unmonitored sites. Although there tend to be exceptions to any generalization, the suggested summary urban runoff characteristics given in Table 6-17 of the report are recommended for planning level purposes as the best estimates, lacking local information to the contrary.

RECEIVING WATER EFFECTS

General

The effects of urban runoff on receiving water quality are highly site-specific. They depend on the type, size, and hydrology of the water body; the urban runoff quantity and quality characteristics; the designated beneficial use; and the concentration levels of the specific pollutants that affect that use.

The conclusions which follow are based on screening analyses performed by NURP, observations and conclusions drawn by individual NURP projects that examined receiving water effects in differing levels of detail and rigor, and NURP's three levels of problem definition. Conclusions are organized on the basis of water body type: rivers and streams, lakes, estuaries and embayments, and groundwater aquifers. Site-specific exceptions should be expected, but the statements presented are believed to provide an accurate perspective on the general tendency of urban runoff to contribute significantly to water quality problems.

Rivers and Streams

1. Frequent exceedances of heavy metals ambient water quality criteria for freshwater aquatic life are produced by urban runoff.

   The Denver NURP project found that in-stream concentrations of copper, lead, zinc, and cadmium exceeded State ambient water quality standards for the South Platte River during essentially all storm events.

NURP screening analyses suggest that frequent exceedances of both EPA 24-hour and maximum water quality criteria for heavy metals should be expected on a relatively general basis.

2. <u>Although a significant number of problem situations could result from heavy metals in urban runoff, levels of freshwater aquatic life use impairment suggested by the magnitude and frequency of ambient criteria exceedances were not observed.</u>

   Based upon the magnitude and frequency of freshwater aquatic life ambient criteria exceedances, one would expect to observe impairment of this beneficial use in most streams that receive urban runoff discharges. However, those NURP project studies which examined this issue did not report significant use impairment problems associated with urban runoff.

   The Bellevue, Washington NURP project concluded that toxic effects of urban runoff pollutants did not appear to be a significant factor.

   The Tampa, Florida NURP project conducted biological studies of the impact of stormwater runoff upon the biological community of the Hillsborough River. They conducted animal bioassay experiments on five sensitive species in two samples of urban runoff from the Arctic Street drainage basin. Thirty-two bioassay experiments were completed including 22 acute tests and 10 chronic tests. Neither sample of stormwater was acutely toxic to test organisms. Long-term chronic experiments were undertaken with two species and resulted in no significant effects attributable to stormwater exposure.

   NURP screening analyses suggest that the potential of urban runoff to seriously impair this beneficial use will be strongly influenced by local conditions and the frequency of occurrence of concentration levels which produce toxic effects under the intermittent, short duration exposures typically produced by urban runoff.

   While the application of the screening analysis to the Bellevue and Tampa situations supports the absence of a problem situation in these cases, it also suggests that a significant number of problem situations should be expected. Therefore, although not the general, ubiquitous problem situation that criteria exceedances would suggest, there are site-specific situations in which urban runoff could be expected to cause significant impairment of freshwater aquatic life uses.

   Because of the inconsistency between criteria exceedances and observed use impairments due to urban runoff, adaptation of current ambient quality criteria to better reflect use impacts where pollutant exposures are intermittent and of short duration appears to be a useful area for further investigation.

3. <u>Copper, lead and zinc appear to pose a significant threat to aquatic life uses in some areas of the country. Copper is suggested to be the most significant of the three.</u>

   Regional differences in surface water hardness, which has a strong influence on toxicity, in conjunction with regional variations in stream flow and rainfall result in significant differences in susceptibility to adverse impacts around the nation.

The southern and southeastern regions of the country are the most susceptible to aquatic life effects due to heavy metals, with the northeast also a sensitive area, although somewhat less so.

Copper is the major toxic metal in urban runoff, with lead and zinc also prevalent but a problem in more restricted cases. Copper discharges in urban runoff are, in all but the most favorable cases, a significant threat to aquatic life uses in the southeast and southern regions of the country. In the northeast, problems would be expected only in rather unfavorable conditions (large urban area contribution and high site concentrations). In the remainder of the country (and for the other metals) problems would only be expected under quite unfavorable site conditions. These statements are based on total metal concentrations.

4. <u>Organic priority pollutants in urban runoff do not appear to pose a general threat to freshwater aquatic life.</u>

   This conclusion is based on limited data on the frequency with which organics are found in urban runoff discharges and measured end-of-pipe concentrations relative to published toxic criteria. One unusually high pentachlorophenol concentration of 115 μg/l resulted in the only exceedance of the organoleptic criteria. This observation and one for chlordane exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentochlorophenol, bis (2-ethylhexyl) phlhalate, γ-hexachlorocyclohexane (lindane), α-endosulfan, and chlordane.

5. <u>The physical aspects of urban runoff, e.g., erosion and scour, can be a significant cause of habitat disruption and can affect the type of fishery present. However, this area was studied only incidentally by several of the projects under the NURP program and more concentrated study is necessary.</u>

   The Metropolitan Washington Council of Governments (MWCOG) NURP project did an analysis of fish diversity in the Seneca Creek Watershed, 20 miles northwest of Washington, D.C. In this study, specific changes in fishery diversity were identified due to urbanization in some of the subwatersheds. Specifically, the number of fish species present are reduced and the types of species present changed dramatically, e.g., environmentally sensitive species were replaced with more tolerant species. For example, the Blacknose Dace replaced the Mottled Sculpin. MWCOG concluded that the changes in fish diversity were due to habitat deterioration caused by the physical aspects of urban runoff.

   The Bellevue, Washington NURP project concluded that habitat changes (streambed scour and sedimentation) had a more significant effect than pollutant concentrations, for the changes produced by urbanization.

6. <u>Several projects identified possible problems in the sediments because of the build-up of priority pollutants contributed wholly or in part by urban runoff. However, the NURP studies in this area were few in number</u>

and limited in scope, and the findings must be considered only indicative of the need for further study, particularly as to long-term impacts.

The Denver NURP project found significant quantities of copper, lead, zinc, and cadmium in river sediments. The Denver Regional Council of Governments is concerned that during periods of continuous low flow, lead may reach levels capable of adversely affecting fish.

The Milwaukee NURP project reported the observation of elevated levels of heavy metals, particularly lead, in the sediments of a river receiving urban runoff.

7. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in most rivers and streams.

   Violations of the fecal coliform standard were reported by a number of NURP projects. In some instances, high fecal coliform counts may not cause actual use impairments due to the location of the urban runoff discharge relative to swimming areas and the degree of dilution or dispersal and rate of die off.

   Coliform bacteria are generally accepted to be a useful indicator of the possible presence of human pathogens when the source of contamination is sanitary sewage. However, no such relationship has been demonstrated for urban runoff. Therefore, the use of coliforms as an indicator of human health risk when the sole source of contamination is urban runoff, warrants further investigation.

8. Domestic water supply systems with intakes located on streams in close proximity to urban runoff discharges are encouraged to check for priority pollutants which have been detected in urban runoff, particularly those in the organic category.

   Sixty-three of a possible 106 organics were detected in urban runoff samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22 percent), followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported at frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single halogenated aliphatic.

Lakes

1. Nutrients in urban runoff may accelerate eutrophication problems and severely limit recreational uses, especially in lakes. However, NURP's lake projects indicate that the degree of beneficial use impairment varies widely, as does the significance of the urban runoff component.

   The Lake Quinsigamond NURP project in Massachusetts identified eutrophication as a major problem in the lake, with urban runoff being a prime contributor of the critical nutrient phosphorus. Point source discharges to the lake have been eliminated almost entirely. However, in spite of the abatement of point sources, survey data indicate that the lake has shown little improvement over the abatement period. In particular, the trophic status of the lake has shown no change, i.e., it is still classified as late mesotrophic-early eutrophic. Substantial growth is projected in the basin, and there is concern that Lake Quinsigamond will become more eutrophic. A proposed water quality management plan for the lake includes the objective of reducing urban runoff pollutant loads.

The Lake George NURP project in New York State also identified increasing eutrophication as a potential problem if current development trends continue. Lake George is not classified as eutrophic, but from 1974 to 1978 algae production in the lake increased logarithmically. Lake George is a very long lake, and the limnological differences between the north and south basins provide evidence of human impact. The more developed, southern portion of the lake exhibits lower transparencies, lower hypolimnetic dissolved oxygen concentrations, higher phosphorus and chlorophyll a concentrations, and a trend toward seasonal blooms of blue-green algae. These differences in water quality indicators are associated with higher levels of cultural activities (e.g., increased sources of phosphorus) in the southern portion of the lake's watershed, and continued development will tend to accentuate the differences.

The Lake George NURP project estimated that urban runoff from developed areas currently accounts for only 13.6 percent of the annual phosphorus loadings to Lake George as a whole. In contrast, developed areas contribute 28.9 percent of the annual phosphorus load to the NURP study areas at the south end of the Lake. Since there are no point source discharges, this phosphorus loading is due solely to urban runoff. These data illustrate the significant impact of urbanization on phosphorus loads.

The NURP screening analysis suggests that lakes for which the contributions of urban runoff are significant in relation to other nonpoint sources (even in the absence of point source discharges) are indicated to be highly susceptible to eutrophication and that urban runoff control may be warranted in such situations.

2. <u>Coliform bacteria discharges in urban runoff have a significant negative impact on the recreational uses of lakes.</u>

As was the case with rivers and streams, coliform bacteria in urban runoff can cause violations of criteria for the recreational use of lakes. When unusually high fecal coliform counts are observed, they may be partially attributable to sanitary sewage contamination, in which case significant health risks may be involved.

The Lake Quinsigamond NURP project in Massachusetts found that bacterial pollution was widespread throughout the drainage basin. In all cases where samples were taken, fecal coliforms were in excess of 10,000 counts per 100 ml, with conditions worse in the Belmont street storm drains. This project concluded that the very high fecal coliform counts in their stormwater are at least partially due to sewage contamination apparently entering the stormwater system throughout the local catchment.

The sources of sewage contamination are leaking septic tanks, infiltration from sanitary sewers into storm sewers, and leakage at manholes. In the northern basin, the high fecal coliform counts are attributed to known sewage contamination sources on Poor Farm Brook. The data from the project suggest that it would be unwise to permit body contact recreation in the northern basin of the lake during or immediately following significant storm events. The project concluded that disinfection at selected storm drains should be considered in the future, especially if the sewage contamination cannot be eliminated.

The Mystic River NURP project in Massachusetts found various areas where fecal coliform counts were extremely high in urban stormwater. Fecal coliform levels of up to one million with an average of 178,000/100 ml were recorded in Sweetwater Brook, a tributary to Mystic River, during wet weather. These high fecal coliform levels were specifically attributed to surcharging in their sanitary sewers, which caused sanitary sewage to overflow into their storm drains via the combined manholes present in this cathcment. Fecal coliform levels above the class B fecal coliform standard of 200 per 100 ml were found in approximately one-third of the samples tested in the upper and lower forebays of the Upper Mystic Lake and occasionally near the lake's outlet. In addition, Sandy Beach, a public swimming area on Upper Mystic Lake, exceeded the State fecal coliform criteria in July of 1982, and warnings that swimming may be hazardous to public health were posted for several days. It is important to note that sewage contamination of surface waters is a major problem in the watershed. The project concluded that urban runoff contributes to the bacteria load during wet weather but, comparatively, is much less significant than the sanitary sources.

Estuaries and Embayments

1. Adverse effects of urban runoff in marine waters will be a highly specific local situation. Though estuaries and embayments were studied to a very limited extent in NURP, they are not believed to be generally threatened by urban runoff, though specific instances where use is impaired or denied can be of significant local and even regional importance. Coliform bacteria present in urban runoff is the primary pollutant of concern, causing direct impacts on shellfish harvesting and beach closures.

   The significant impact of urban runoff on shellfish harvesting has been well documented by the Long Island, New York NURP project. In this project, stormwater runoff was identified as the major source of bacterial loading to marine waters and, thus, the indirect cause of the denial of certification by the New York State Department of Conservation for about one-fourth of the shellfishing area. Much of this area is along the south shore, where the annual commercial shellfish harvest is valued at approximately $17.5 million.

   The Myrtle Beach, South Carolina NURP project found that stormwater discharges from the City of Myrtle Beach directly onto the beach showed high bacterial counts for short durations immediately after storm events. In many instances these counts violated EPA water quality criteria for aquatic life and contact recreation. The high bacteria counts, however, were associated with standing pools formed at the end of collectors for brief periods following the cessation of rainfall and before the runoff percolated into the sand. Consequently, the threat to public health was not considered great enough to warrant closure of the beach.

Groundwater Aquifers

1. Groundwater aquifers that receive deliberate recharge of urban runoff do not appear to be imminently threatened by this practice at the two locations where it was investigated.

   Two NURP projects (Long Island and Fresno) are situated over sole source acquifers. They have been practicing recharge with urban runoff for two decades or more at some sites, and extensively investigated the impact of this practice on the quality of their groundwater. They both found that soil processes are efficient in retaining urban runoff pollutants quite close to the land surface, and concluded that no change in the use of recharge basins is warranted.

   Despite the fact that some of these basins have been in service for relatively long periods of time and pollutant breakthrough of the upper soil layers has not occurred, the ability of the soil to continue to retain pollutants is unknown. Further attention to this issue is recommended.

CONTROL EFFECTIVENESS

General

A limited number of techniques for the control of urban runoff quality were evaluated by the NURP program. The set is considerably smaller than previously published lists of potential management practices. Since the control approaches that were investigated were selected at the local level, the choices may be taken as an initial indication of local perceptions regarding practicality and feasibility from the standpoint of implementation.

Conclusions

1. There is a strong preference for detention devices, street sweeping, and recharge devices as reflected by the control measures selected at the local level for detailed investigation. Interest was also shown in grass swales and wetlands.

   Six NURP projects monitored the performance of a total of 14 detention devices. Five separate projects conducted in-depth studies of the effectiveness of street sweeping on the control of urban runoff quality. A total of 17 separate study catchments were involved in this effort. Three NURP projects examined either the potential of recharge devices to reduce discharges of urban runoff to surface waters or the potential of the practice to contaminate groundwaters. A total of 12 separate sites were covered by this effort.

Grass swales were studied by two NURP projects. Two swales in existing residential areas, and one experimental swale constructed to serve a commercial parking lot were studied.

A number of NURP projects indicated interest in wetlands for improving urban runoff quality at early stages of the program. Only one allocated monitoring activity to this control measure, however.

Various other management practices were identified as having local interest by individual NURP projects, but none of them was allocated the necessary resources to be pursued to a point which allowed an evaluation of their ability to control pollution from urban runoff. Management practices in this category included urban housekeeping (e.g., litter programs, catch basin cleaning, pet ordinances) and public information programs.

2. <u>Detention basins are capable of providing very effective removal of pollutants in urban runoff. Both the design concept and the size of the basin in relation to the urban area served have a critical influence on performance capability</u>.

   Wet basins (designs which maintain a permanent water pool) have the greatest performance capabilities. Observed pollutant reductions varied from excellent to very poor in the basins which were monitored. However, when basins are adequately sized, particulate removals in excess of 90 percent (TSS, lead) can be obtained. Pollutants with significant soluble fractions in urban runoff show lower reductions; on the order of 65 percent for total P and approximately 50 percent for BOD, COD, TKN, Copper, and Zinc. Results indicate that biological processes which are operative in the permanent pool produce significant reductions (50 percent or more) in soluble nutrients, nitrate and soluble phosphorus. These performance characteristics are indicated by both the NURP analysis results and conclusions reached by individual projects.

   Dry basins, (conventional stormwater management basins), which are designed to attenuate peak runoff rates and hence only very briefly detain portions of flow from the larger storms, are indicated by NURP data to be essentially ineffective for reducing pollutant loads.

   Dual-purpose basins (conventional dry basins with modified outlet structures which significantly extend detention time) are suggested by limited NURP data to provide effective reductions in urban runoff loads. Performance may approach that of wet ponds; however, the additional processes which reduce soluble nutrient forms do not appear to be operative in these basins. This design concept is particularly promising because it represents a cost effective approach to combining flood control and runoff quality control and because of the potential for converting existing conventional stormwater management ponds.

   Approximate costs of wet pond designs are estimated to be in the order of \$500 to \$1500 per acre of urban area served, for on-site applications serving relatively small urban areas, and about \$100 to \$250 per acre of urban area for off-site applications serving relatively large urban areas. The costs reflect present value amounts which include both capital and operating costs. The difference is due to an economy of scale associated with large basin volumes. The range reflects differences in size required to produce particulate removals in the order of 50 percent or 90 percent. Annual costs per acre of urban area served are estimated at $60 to $175, and $10 to $25 respectively.

3. Recharge Devices are capable of providing very effective control of urban runoff pollutant discharges to surface waters. Although continued attention is warranted, present evidence does not indicate that significant groundwater contamination will result from this practice.

   Both individual project results and NURP screening analyses indicate that adequately sized recharge devices are capable of providing high levels of reduction in direct discharges of urban runoff to surface waters. The level of performance will depend on both the size of the unit and the soil permeability.

   Application will be restricted to areas where conditions are favorable. Soil type, depth to groundwater, land slopes, and proximity of water supply wells will all influence the appropriateness of this control technique.

   Surface accumulations which result from the high efficiency of soils to retain pollutants, suggest further attention in applications where dual purpose recharge areas also serve as recreational fields or playground areas.

4. Street sweeping is generally ineffective as a technique for improving the quality of urban runoff.

   Five NURP projects evaluated street sweeping as a management practice to control pollutants in urban runoff. Four of these projects concluded that street sweeping was not effective for this purpose. The fifth, which had pronounced wet and dry seasons, believed that sweeping just prior to the rainy season could produce some benefit in terms of reduced pollution in urban runoff.

   A large data base on the quality of urban runoff from street sweeping test sites was obtained. At 10 study sites selected for detailed analysis, a total of 381 storm events were monitored under control conditions, and an additional 277 events during periods when street sweeping operations were in effect. Analysis of these data indicated that no significant reductions in pollutant concentrations in urban runoff were produced by street sweeping.

   There may be special cases in which street cleaning applied at restricted locations or times of year could provide improvements in urban runoff quality. Some examples that have been suggested, though not demonstrated by the NURP program, include periods following snow melt or leaf fall, or urban neighborhoods where the general level of cleanliness could be significantly improved.

5. Grass swales can provide moderate improvements in urban runoff quality. Design conditions are important. Additional study could significantly enhance the performance capabilities of swales.

   Concentration reductions of about 50 percent for heavy metals, and 25 percent for COD, nitrate, and ammonia were observed in one of the swales studied. However the swale was ineffective in reducing concentrations of organic nitrogen, phosphorus, or bacterial species. Two other swales studied failed to demonstrate any quality improvements in the urban runoff passing through them.

   Evaluations by the NURP projects involved concluded, however, that this was an attractive control technique whose performance could be improved substantially by application of appropriate design considerations. Additional study to develop such information was recommended.

   Design considerations cited included slope, vegetation type and maintenance, control of flow velocity and residence time, and enhancement of infiltration. The latter factor could produce load reductions greater than those inferred from concentration changes and effect reductions in those pollutant species which are not attenuated by flow through the swale.

6. Wetlands are considered to be a promising technique for control of urban runoff quality. However, neither performance characteristics nor design characteristics in relation to performance were developed by NURP.

   Although a number of projects indicated interest, only one assigned NURP monitoring activity to a wetland. This was a natural wetland, and flows passing though it were uncontrolled. Results suggest its potential to improve quality, but the investigation was not adequate to associate necessary design factors to performance capability. Additional attention to this control technique would be useful, and should include factors such as the need for maintenance harvesting to prevent constituent recycling.

ISSUES

A number of issues with respect to managing and controlling urban runoff emerge from the conclusions summarized above. In some instances they represent the need for additional data/information or for further study. In others they point to the need for follow-up activity by EPA, State, or local officials to assemble and disseminate what is already known regarding water quality problems caused by urban runoff and solutions.

Sediments

The nature and scope of the potential long-term threat posed by nutrient and toxic pollutant accumulation in the sediments of urban lakes and streams requires further study. A related issue is the safe and environmentally sound disposal of sediments collected in detention basins used to control urban runoff.

Priority Pollutants

NURP clearly demonstrated that many priority pollutants can be found in urban runoff and noted that a serious human health risk could exist when water supply intakes are in close proximity to urban stormwater discharges. However, questions related to the sources, fate, and transport mechanisms of priority pollutants borne by urban runoff and their frequencies of occurrence will require further study.

Rainfall pH Effects

The relationship between pH and heavy metal values in urban runoff has not been established and needs further study. Several NURP projects (mostly in the northeastern states) attributed high heavy metals concentrations in urban runoff to the effects of acid rain. Although it is quite plausible that acid rain increases the level of pollutants in urban runoff and may transform them to more toxic and more easily assimilated forms, further study is required to support this speculation.

Industrial Runoff

No truly industrial sites (as opposed to industrial parks) were included in any of the NURP projects. A very limited body of data suggests, however, that runoff from industrial sites may have significantly higher contaminant levels than runoff from other urban land use sites, and this issue should be investigated further.

Central Business Districts

Data on the characteristics of urban runoff from central business districts are quite limited as opposed to other land use categories investigated by NURP. The data do suggest, however, that some sites may produce pollutant concentrations in runoff that are significantly higher than those from other sites in a given urban area. When combined with their typically high degrees of imperviousness, the pollutant loads from central business districts can be quite high indeed. The opportunities for control in central business districts are quite limited, however.

Physical Effects

Several projects concluded that the physical impacts of urban runoff upon receiving waters have received too little attention and, in some cases, are more important determinants of beneficial use attainment than chemical pollutants. This contention requires much more detailed documentation.

Synergy

NURP did not evaluate the synergistic effects that might result from pollutant concentrations experienced in stormwater runoff, in association with pH and temperature ranges that occur in the receiving waters. This type of investigation might reveal that control of a specific parameter, such as pH, would adequately reduce an adverse synergistic effect caused by the presence of other pollutants in combination and be the most cost effective solution. Further investigations should include this issue.

Opportunities for Control

Based upon the results of NURP's evaluation of the performance of urban runoff controls, opportunities for significant control of urban runoff quality are much greater for newly developing areas. Institutional considerations and availability of space are the key factors. Guidance on this issue in a form useful to States and urban planning authorities should be prepared and issued.

Wet Weather Water Quality Standards

The NURP experience suggests that EPA should evaluate the possible need to develop "wet weather" standards, criteria, or modifications to ambient criteria to reflect differences in impact due to the intermittent, short duration exposures characteristic of urban runoff and other nonpoint source discharges.

Coliform Bacteria

The appropriateness of using coliform bacteria as indicator organisms for human health risk where the source is exclusively urban runoff warrants further investigation.

Wetlands

The use of wetlands as a control measure is of great interest in many areas, but the necessary information on design performance relationships required before cost effective applications can be considered has not been adequately documented. The environmental impacts of such use upon wetlands is a critical issue which, at present, has been addressed marginally, if at all.

Swales

The use of grass swales was suggested by two NURP projects to represent a very promising control opportunity. However, their performance is very dependent upon design features about which information is lacking. Further work to address this deficiency and appropriate maintenance practices appears warranted.

Illicit Connections

A number of the NURP projects identified what appeared to be illicit connections of sanitary discharges to stormwater sewer systems, resulting in high bacterial counts and dangers to public health. The costs and complications of locating and eliminating such connections may pose a substantial problem in urban areas, but the opportunities for dramatic improvement in the quality of urban stormwater discharges certainly exist where this can be accomplished. Although not emphasized in the NURP effort, other than to assure that the selected monitoring sites were free from sanitary sewage contamination, this BMP is clearly a desirable one to pursue.

Erosion Controls

NURP did not consider conventional erosion control measures because the information base concerning them was considered to be adequate. They are effective, and their use should be encouraged.

Combined Sewer Overflows

In order to address urban runoff from separate storm sewers, NURP avoided any sites where combined sewers existed. However, in view of their relative levels of contamination, priority should be given to control of combined sewer overflows.

Implementation Guidance

The NURP studies have greatly increased our knowledge of the characteristics of urban runoff, its effects upon designated uses, and of the performance efficiencies of selected control measures. They have also confirmed earlier impressions that some States and local communities have actually begun to develop and implement stormwater management programs incorporating water quality objectives. However, such management initiatives are, at present, scattered and localized. The experience gained from such efforts is both needed and sought after by many other States and localities. Documentation, evaluation, refinement and transfer of management and financing mechanisms/ arrangements, of simple and reliable problem assessment methodologies, and of implementation guidance which can be used by planners and officials at the State and local level are urgently needed as is a forum for the sharing of experiences by those already involved, both among themselves and with those who are about to address nonpoint source issues.

APPENDIX
THE NATIONWIDE URBAN RUNOFF PROGRAM

Program Design

NURP was not intended to be a research program, per se, and was not designed as such. Rather, the program was intended to be a support function which would provide information and methodologies for water quality planning efforts. Therefore, wherever possible, the projects selected were ones where the work undertaken would complete the urban runoff elements of formal water quality management plans and the results were likely to be incorporated in future plan updates and lead to implementation of management recommendations. Conduct of the program provided direction and assistance to 28 separate and distinct planning projects, whose locations are shown in Figure 1 and listed in Table 1, but the results will be of value to many other planning efforts. NURP also acted as a clearinghouse and, in that capacity, provided a common communication link to and among the 28 projects.

The NURP effort began with a careful review of what was known about urban runoff mechanisms, problems, and controls, and then built upon this base. The twin objectives of the program were to provide credible information on which Federal, State, and local decision makers could base future urban runoff management decisions and to support both planning and implementation efforts at the 28 project locations.

An early step in implementing the NURP program involved identifying a limited number of locations where intensive data gathering and study could be done. Candidate locations were assessed relative to three basic selection criteria:

- Meeting program objectives;

- Developing implementation plans for those areas; and

- Demonstrating transferability, so that solutions and knowledge gained in the study area could be applied in other areas, without need for intensive, duplicative data gathering efforts.

The program design used for NURP included providing a full range of technical and management assistance to each project as the needs arose. Several forums for the communication of experience and sharing of data were provided through semi-annual meetings involving participants from all projects. The roles and responsibilities of the various State, local, and regional agencies and participating Federal agencies were clearly defined and communicated at the outset. These were reviewed and revised where warranted as the projects progressed.

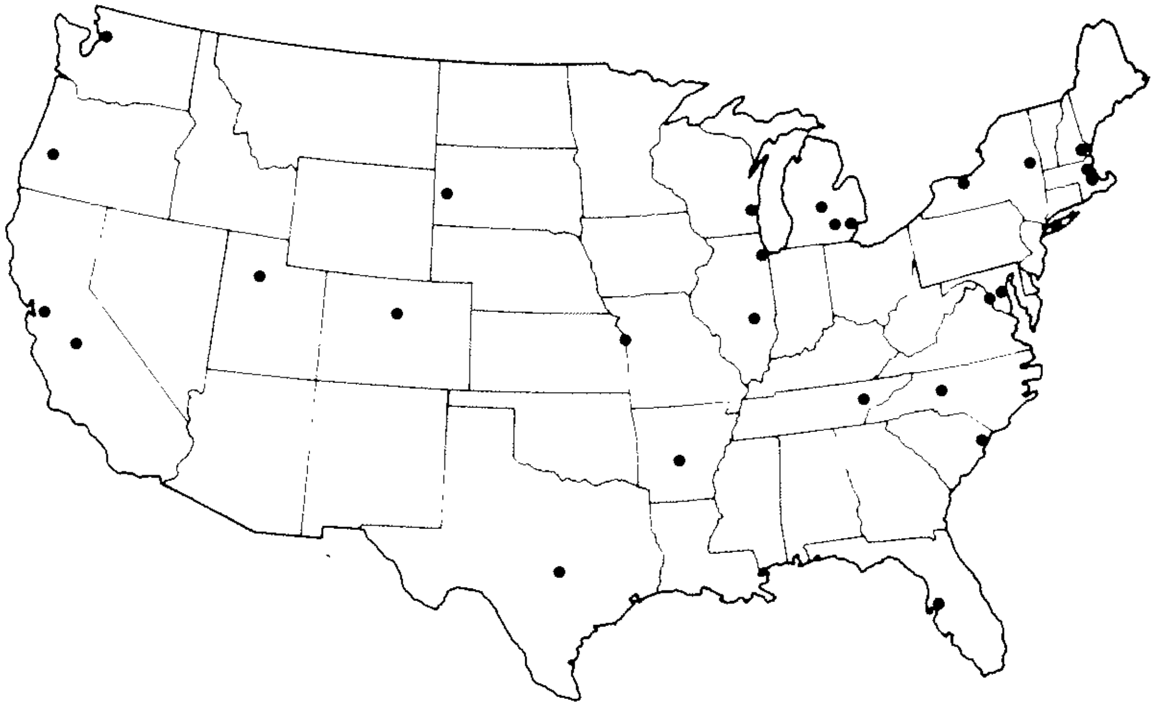


Figure 1. Locations of the 28 NURP Projects

TABLE 1. NURP PROJECT LOCATIONS

EPA Region	NURP Code	Project Name/Location	EPA Region	NURP Code	Project Name/Location
I	MA1	Lake Quinsigamond (Boston Area)	V	IL1	Champaign-Urbana, Illinois
				IL2	Lake Ellyn (Chicago Area)
	MA2	Upper Mystic (Boston Area)		MI1	Lansing, Michigan
	NH1	Durham, New Hampshire		MI2	SEMCOG (Detroit Area)
II	NY1	Long Island (Nassau and Suffolk Counties)		MI3	Ann Arbor, Michigan
				WI1	Milwaukee, Wisconsin
	NY2	Lake George	VI	AR1	Little Rock, Arkansas
	NY3	Irondequoit Bay (Pochester Area)		TX1	Austin, Texas
			VII	KS1	Kansas City
III	DC1	WASHCOG (Washington, D.C. Metropolitan Area)	VIII	CO1	Denver, Colorado
				SD1	Rapid City, South Dakota
	MD1	Baltimore, Maryland		UT1	Salt Lake City, Utah
IV	FL1	Tampa, Florida	IX	CA1	Coyote Creek (San Francisco Area)
	NC1	Winston-Salem, North Carolina			
	SC1	Myrtle Beach, South Carolina		CA2	Fresno, California
	TN1	Knoxville, Tennessee	X	OR1	Springfield-Eugene, Oregon
				WA1	Bellevue (Seattle Area)

The 28 NURP projects were managed by designated State, county, city, or regional governmental associations. The U.S. Geological Survey (USGS) was involved with EPA as a cooperator, through an inter-agency agreement, on 11 of the NURP projects. The Tennessee Valley Authority was also involved in one project.

Project Selection

Projects were selected from among the 93 Areawide Agencies that had identified urban runoff as one of their significant problems. The intention was to build upon what these agencies had already accomplished in their earlier programs. Also, projects that would be a part of this program were screened to be sure that they represented a broad range of certain characteristics (e.g., hydrologic regimes, land uses, populations, drainage system types). Actual selection of projects was a joint effort among the States, local governments, and Regional EPA offices. The five major criteria used to screen candidate projects were as follows:

1. Problem Identified. Had a problem relative to urban runoff actually been identified? Could that problem be directly related to separate storm sewer discharges? What pollutant or pollutants were thought to be causing the problem? Using the NURP problem identification categories, what was the "problem" (i.e., denying a beneficial use, violating a State water quality standard, or public concern)?

2. Type of Receiving Water. The effects of stormwater runoff on receiving water quality were the NURP program's ultimate concern. Because flowing streams, tidal rivers, estuaries, oceans, impoundments, and lakes all have different hydrologic and water quality responses, the types of receiving waters associated with each candidate project had to be examined to ensure that an appropriately representative mix was included in the overall NURP program.

3. Hydrologic Characteristics. The pattern of rainfall in the study area is perhaps the single most important factor in studying urban runoff phenomena, because it provides the means of conveyance of pollutants from their source to the receiving water. For this reason, projects in locations having different hydrologic regimes were chosen for the program.

4. Urban Characteristics. Characteristics such as population density, age of community, and land use were considered as possible indicators of the waste loads and ultimately the rainfall-runoff water quality relationship. The type of sewerage system was another factor considered (e.g., whether it is combined, separate, or mixed; how severe the infiltration and inflow problems may be). Such factors have different effects on the quantity and quality of storm runoff, and were balanced as well as possible in selecting projects.

5. Beneficial Use of Receiving Water. Because this factor greatly affects the type of control measure that would be appropriate, attempts were made to include a wide range in selecting projects.

Although these were the primary criteria used to identify potential projects, other factors also had to be considered (e.g., the applicant agencies' willingness to participate, the State's acceptance of the project, the experience of the proposed project teams). Because the NURP program used planning grants (not research funds) a major consideration was the anticipated working relationships with local public agencies and the applicants' ability to raise local matching funds.

Program Assistance

Technical expertise and resources available for urban runoff planning varied among the various projects participating in NURP. Therefore, the program strategy called for providing a broad spectrum of technical assistance to each project as needed and for intercommunication of experiences and sharing of data in a timely manner.

Assistance was also provided to the applicants in developing their final work plans. This was done to ensure that there would be consistency among methods, especially in the collection of data. If there were to be differences in data from city to city, they must be due to the characteristics of each city and not a result of how the data were obtained.

Assistance with instrumentation was provided during the program in the form of information on available equipment, installation, calibration, etc. Because one of the more important elements of a data collection program is the "goodness" or quality of the data themselves, questionable data would be of little use. Accordingly, a quality assurance and quality control element was required in the plans for each project.

Periodic visits were made to each project site to ensure that the participants were provided opportunities to discuss any problems, technical or administrative. The visiting team typically included an EPA Regional Office representative, an EPA Headquarters representative, and one or two experienced consultants. All interested parties, including representatives from State or local governments, were requested to attend those visits.

As the projects moved farther into their planned activities and the time for data analysis approached, each project was required to describe how they were going to analyze their data. No single method was recommended for each project, because it was believed that a broad diversity of available methods would be suitable, if used properly. Guidance on proper use was provided as a part of technical assistance through project visits and special workshops for this purpose.

Communication

It was intended that the entire group of NURP participants function as a single team. Accordingly, a communication program was developed. National meetings were conducted semi-annually so that key personnel from the individual projects would have an opportunity to discuss their experiences and findings.

Reports were required of each project quarterly. EPA Headquarters also provided composite quarterly reports summarizing the status of each project and discussing problems encountered and solutions found.

OUTPUTS TRANSFERABLE TO STATE AND LOCAL GOVERNMENTS

The program has yielded a great deal of information which will be useful for a broad spectrum of planning activities for many years. Furthermore, it has fostered valuable cooperative relationships among planning and regulatory agencies. The most tangible products of the program are this report, the reports of various grantees (available under separate cover), and several technical reports which focus on specialized aspects of the program, its techniques, and its findings. In addition, a considerable number of individual articles drawing on information developed under the NURP program have already appeared in the technical literature and address specific technical or planning aspects of urban runoff.

At the time of publication of this Final Report, the main technical effort of the NURP program is complete; the field studies and the analysis of most of the resultant data are complete enough that the findings reported herein can be taken with confidence. However, there is still some work in progress to make certain details of the program available for future use. The products of this on-going work include:

- A detailed database which has been compiled to make technical information from the 28 projects available for review and use (DECEMBER 1985);

- A technical report which focuses on the program's studies and findings relative to detention and recharge devices (MAY 1984);

- A technical report on urban runoff effects on the water quality of rivers and streams (MARCH 1984); and

- A technical report on the effectiveness of street sweeping as a potential "best management practice" for water pollution control (MAY 1984).

This report supersedes the earlier NURP publication, "Preliminary Results of the Nationwide Urban Runoff Program," March 1982. Information presented there has been expanded, updated, and in some cases revised.

*U.S. GOVERNMENT PRINTING OFFICE : 1984 0-421-082/519